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RAIN WATER HARVESTING FOR PLANTING AND GROWING TREES TO GREEN THE POLYTECHNIC CAMPUS: A CASE STUDY OF BOLGATANGA POLYTECHNIC

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ABSTRACT: *The Upper East Region of Ghana is located in the Guinea Savannah agro-ecological zone with a sparse tree population. The Region suffers high unpredictable rainfall patterns imposing drought conditions with consequences on crop yield variability and poor vegetation cover. As a result, at inception of the Polytechnic, there were very limited shade trees in the Polytechnic campus where students could sit to relax or learn. Harvesting rainwater in wet periods, and utilizing the same for planting and growing trees offers a promising solution in this fragile part of Ghana. As part of the larger effort to make the Polytechnic environment suitable for teaching and learning, rain water was harvested for planting and growing trees in the Polytechnic campus. This paper presents a qualitative report of project activities and results. Tree planting project hinges on proper management of the established trees and shrubs. Planting trees is just one step, but its management was very crucial to the success and fruition of the project. Also critical was stakeholder consultations on project goals and aims which enabled a sense of ownership for the project. Overall, after ten years of the project, there has been a significant improvement in the tree and shrub cover in the Polytechnic campus. It is concluded that adding trees to schools is a great way to make campuses more welcoming, provide shade for recreational purposes, and as well foster environmental stewardship. The Government should as part of project procurement procedures for schools legislate that all new buildings should incorporate tree planting from inception. The care of the trees can then be the responsibility of school management after the buildings have been completed and handed over.*

KEYWORDS: Rain, Water, Harvesting, Tree Planting, Growing

INTRODUCTION

Ghana is a West African country bordered to the north by Burkina Faso, to the west by la Côte d'Ivoire, and to the east by Togo. It has a population of 25 million people (GSS, 2014). The climate of Ghana is tropical, but temperatures vary with season and elevation (Wood, 2013). There are two major seasons in the country, the rainy and the dry season. The northern part of Ghana is located in the Guinea Savannah agro-ecological zone with a monomodal rainy season, starting in April/May and ending in September/October, and an annual rainfall varying between 900 mm and 1100 mm (Tsigbey, Brandenburg, & Clotey, 2002). Northern Ghana is made up of three administrative regions (i.e., Northern, Upper East, and Upper West). This area suffers high unpredictable rainfall patterns imposing drought conditions with consequences on crop yield variability, food security, and vegetation cover (CIDA, 1999, Wood, 2013).

Climate change will affect rainfall and increase evaporation, which will put increasing pressures on our ecosystems (UNEP, 2009). At the global level, trees and forests are closely

linked with weather patterns and also the maintenance of a crucial balance in nature (Verheij, 2004). Among the major challenges facing the world today is deforestation, land degradation, unsustainable farming practices, loss of biodiversity, increased risks of climate change and rising hunger, poverty and malnutrition (Oke & Jamala, 2013). Harvesting rainwater in wet periods, and utilizing the same for planting and growing trees offers a promising solution in the fragile, rainfed regions of the world (UNEP, 2009). Particularly, there is considerable scope for the collection of rainwater when it falls, before huge losses occur due to evaporation, transpiration, and runoff all of which has consequences for the environment (UNEP, 2013).

As part of the larger effort at conserving the Polytechnic environment, funding was sought from the Teaching and Learning Innovation Fund (TALIF) for harvesting rain water to plant and grow trees in the Polytechnic campus. TALIF was launched in March, 2004 as a component of Ghana's Education Sector Project (EdSeP). TALIF was designed as a development tool to enhance the ability of the country's tertiary institutions to fulfill their primary responsibilities of teaching, learning and extension of knowledge to the wider community. This paper highlights activities implemented during the project lives span. It also discusses lessons learnt and the challenges encountered in the course of the project. In next to follow, we present a brief background and description of the project. This is followed by the materials and methods used for the project. Then in the concluding part, we discuss the lessons learnt and challenges encountered. The overarching aim of the paper is to draw lessons for future interventions of similar projects.

Background

A Ghana Government White Paper in 1993 gave prominence to polytechnic education following the promulgation of the Polytechnic Law, 1992 (PNDCL 321) which upgraded Polytechnics to tertiary status. Thereafter, regionally based Polytechnics were established in line with government policy of making polytechnic education accessible throughout the country. Consequently, Bolgatanga Polytechnic was established in the Upper East Region in 1999 and started operations in 2003. The mandate of Polytechnics is to deliver quality Higher National Diploma (HND) products that are career-focused, hands-on to problem solving and responsive to the needs and demands of society, employers and professional bodies (Nsiah-Gyabaah, 2005).

As indicated above, the Upper East Region is located in the Guinea Savannah agro-ecological zone with a sparse tree population. Much of the region is an example of an extreme anthropogenic landscape (Blench, 1999). Environmental degradation in this part of Ghana appears to be well advanced in comparison to the southern part; the reasons being as follows (Blench, 1999): a) frequent widespread bush fires; b) uncontrolled firewood cutting and charcoal production; c) absence of restraints on animal browsing; d) the removal of trees to increase cropping space; and e) high human population density in some areas. As a result, at the inception of the Polytechnic, there were very limited shade trees in the Polytechnic campus where students could sit to relax or learn. Figure 1 below presents a graphic account of the situation in the Polytechnic by 2003.

Figure 1. A graphic picture of the Polytechnic Campus in 2003

As part of the larger effort to make the Polytechnic environment suitable for teaching and learning, funding was sought from the TALIF for greening the Polytechnic campus. The aim of the project was to harvest rain water to plant and grow trees in order to green the Polytechnic.

Project Description

Rainwater harvesting can be considered any human practice that deliberately captures and stores rainwater for future use (Critchley & Siegert, 1991). Rainwater harvesting represents an adaptation strategy for people living with high rainfall variability, both for domestic supply, and to enhance crop, livestock and other forms of agriculture (UNEP, 2009). It is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions (Boers & Ben-Asher, 1982).

Broadly, rainwater harvesting is characterized by collection, conveyance, storage, and distribution of collected rainwater (Water Aid, 2013). There are two ways of harvesting rainwater (i.e., surface runoff harvesting, and roof top rainwater harvesting).This project adopted the rooftop rain water harvesting approach which is less expensive, and can be very effective if implemented properly (Thomas & Martinson, 2007). In rooftop harvesting, the roof becomes the catchment, and the rainwater is collected from the roof of the building. Its basic components include a roof area, gutters and downspout, above ground or below ground tank, and a pump or gravity for distribution (DTU, 1999).

As indicated above, the aim of the project was to harvest rainwater for planting and growing trees in the Polytechnic campus. Trees are vitally important to people as they provide many products, including food, timber, fuel and medicines for humans and animals (Verheij, 2004). Also, trees can ameliorate climate and human comfort as follows (McPherson & Rowntree, 1993): 1) shading, which reduces the amount of radiant energy absorbed, stored, and radiated by built surfaces; 2) evapotranspiration, which converts radiant energy into latent energy, thereby reducing sensible heat that warms the air; and 3) air flow modification, which affects transport and diffusion of energy, water vapor, and pollutants. Trees also provide environmental benefits including (FITEC, 2000): erosion control, water quality improvement, recreation opportunities, scenic improvement, shelter and shade, and carbon uptake.

One of several integrated strategies used for ensuring sustainable land management centers on planting and protecting trees on farms, or planting trees where they are absent, commonly referred to as *agroforestry* (Fifanou et al. 2011). In this direction, fast-growing nitrogen fixing tree species like Moringa, Sessbania, Leucaena or Gliricidia that give filtered shade were planted. Also, planted were food trees such as Mangoes and Cashew. Similarly, native or indigenous trees that grow easily in local conditions (e.g., *Terminalia superba* (Ofram), and *Khaya* spp (Mahogany), eucalyptus, pine, teak, and neem) were also planted. In addition, decorative or avenue flower species such as Weeping Willow (*Polyathea longifolia*), Eucalythus (*Eucalythus spy*), and Carpet grass (*Azonopus compressus*) were also planted.

MATERIALS AND METHODS

The first step was to gain stakeholder (i.e., Polytechnic community) buy-in to the project. This was through workshops that introduced to staff and students the project aims and objectives. Specifically, this was to help them understand the aims, strategies and the intended outcomes of the project. This way, an appreciation of the significance of the project for the institution was achieved. Thereafter, the following steps were followed: establishment of project implementation committee; survey works, procurement of logistics, tree planting and growing, and monitoring.

1) *Establishment of project implementation committee:* A five member team was formed by management to oversee the project implementation. The team was drawn from members of faculty, administration, and the Student Representative Council (SRC). The Committee's role was to provide advice, ensure delivery of the project outputs and outcomes. Three farm hands were also engaged to be directly in charge of tree planting and cultural practices. The committee was trained on the value of the project, collection and storage of species, tree planting and protection techniques, maintenance, weed control, and watering.

2) *Survey works:* The Polytechnic at the time was still at infancy. However, there was a master plan map stipulating future citing of road net works, hostel buildings, and lecture theaters. Therefore, working with the Development Officer of the institution, a map out and layout of the areas for the trees was done.

3) *Procurement of logistics (Water reservoirs and distribution systems):* TALIF regulations stipulate rigorous procedures for the procurement of goods and services in line with Ghana's Public Procurement Act 2003, (Act 663). In this respect, all the necessary procurement procedures as per the Act were followed in the procurement of logistics, and establishment of water reservoirs, and distribution systems in readiness for the tree planting and growing.

The rainwater was collected in guttering placed around the eaves of one of the buildings in the institution. The guttering drains to a down-pipe, which discharges the water into an underground concrete storage tank constructed for the purpose. This tank (water reservoir) was fitted with water pumps for the distribution of water around the campus. Figure 2 below presents the water reservoir and distribution system which has the capacity to store up to 5000 gallons of water. This enabled the water to be pumped to four other distribution systems within the campus.

Figure 2: Water reservoir and pump station

Also, four water distribution centers were established in strategic locations within the campus linking the pump station. Figure 3 below is a graphic account of one of the distribution centres.

Figure 3. Water reservoir located in a strategic location

4. *Implementation (tree planting and growing):* The success of any tree planting is dependent on site preparation, stock quality, planting and handling techniques, and maintenance (Ogle, 2011). High quality plant materials are desired for planting. Broken, damaged, diseased and substandard tree seedlings should be avoided. The seedlings should be free from bark damage, decay, sunscald, and insects. Key elements of successful planting include proper tree handling, soil cultivation, planting hole depth, root placement, and tree firmness. On the other hand if not done properly, the following may result: inadequate or excessive stocking rate, tree mortality, poor early growth, toppling and subsequent windthrow, and poor tree straightness.

Cultural practices (mulching, watering, fertilizing and pruning) also play an important role in developing and maintaining healthy trees (Bedker, O'Brien, & Mielke, 1995; Gilman, 2011).

Mulching and proper watering are the most important. These two practices can create the cool, moist soil conditions that trees need. The following cultural practices were used in the project for creating optimum conditions for the trees.

a) *Mulching:* Mulching is one of the most beneficial practices that can be used for better tree health (Bedker et al., 1995). Mulches are materials placed over the soil surface to maintain moisture and improve soil conditions. The benefits of proper mulching include the following (International Society of Arboriculture (ISA), (2011): 1) Helps reduce soil moisture loss through evaporation; 2) Helps control weed germination and growth; 3) Insulates soil, protecting roots from extreme temperatures; 4) Can improve soil biology, aeration, structure (aggregation of soil particles), and drainage; 5) Can improve soil fertility; and 6) Inhibits certain plant diseases. Also, the decomposition process helps build new layers of soil with improved structure which aids in better water retention and oxygen exchange. Finally, placing mulch around the base of a tree reduces the likelihood of damaging the stems of the trees. All these benefits create a healthy environment for tree roots, and help promote tree growth and survival. Mulch materials can be classified into organic or synthetic (International Society of Arboriculture (ISA), 2011). In this project, organic mulching consisting of grass straws, leaves and grass clippings were used.

b) *Watering:* Sufficient water is probably the single most important factor in maintaining a healthy tree especially in this part of the country where rainfall is insufficient. As indicated above, water distribution systems were placed in strategic locations in the Polytechnic campus. This enabled the laying of hoses on the ground, and allowing the water to run slowly over the root zones for some of the trees and shrubs. The farm hands engaged purposely for the project watered the trees and shrubs two times a day especially in dry seasons.

c) *Fertilizing:* Fertilization is beneficial only when nutrients are lacking. Reasons to fertilize include the following: to correct a nutrient deficiency, to accelerate growth when trying to establish a new planting quickly, and to maintain health, usually to replenish nitrogen. In this project compound manure was used.

d) *Pruning:* Pruning was done on broken or damaged branches of the trees and shrubs to correct and improve their structure. It was important to leave as much foliage on the site as possible because carbohydrates and other products produced by photosynthesis in the leaves are necessary for root system regeneration and development (Ogle, 2011).

e) *Weed and pest control:* Effective weed control enhances tree survival and growth, and results in faster tree growth (Ogle, 2011). Most plantings require three to five years of weed control. After this period, trees are taller than other vegetation and have developed sufficient root systems to compete with other plant materials on the site. The methods used for controlling competing vegetation included mowing, mulching, and herbicide use.

f) *Tree protection:* The Polytechnic campus at the time of the project was not fenced and thus exposing the young trees and shrubs to animal damage, especially in the dry season. To protect individual trees from such attacks, tree protectors made of mesh were used. The tree protectors were firmly anchored in the soil without disturbing the tree roots. The

tree protectors were high enough to prevent animal attack. Figure 4 below is a graphic account of the tree protectors.

Figure 4. A graphic account of the trees protection

RESULTS

As indicated earlier, the aim of the project was to harvest rain water for planting and growing trees in the Polytechnic campus. The project was started in 2006, and the evaluation was done in 2016 (i.e., ten years later). The scenery at the Polytechnic has changed immensely; green spaces have mushroomed within the campus. Also, not only has the planted areas become attractive, but they also serve as shade for the staff and students, and thus creating an improved environment for teaching and learning. The outcomes of interest are tree success and whether or how the tree planting has improved the Polytechnic environment. We measure tree success in two ways: survival and growth. Survival and its converse, mortality, are commonly mentioned in urban forestry (Roman & Scatena 2011). Our measure of survival is a binary indicator of whether the planted trees or shrubs are still alive at the time of re-inventory. Table 1 below presents planted tree species and avenue or decorative plants and their survival rates.

Table 1. Planted tree species and shrubs and their survival rates

Tree species	Quantity planted (2006)	Quantity alive (2016)	Survival rate (%)
Fruit trees			
Grafted mangoes (Mangitera indica)	200	150	75
Akee apple (Bleghia sapida)	200	100	50
Cashew (Anocardium occidentale)	50	10	20
Shade trees			
Cassia (Cassia Spectabilis)	300	223	74
Montalis (Terminalia Montalis)	200	112	56
Catapa (Terminalia Catapa)	100	76	76
Mahogany (Khaya Senegalensis)	100	54	54
Rain tree (Samanea Saman)	200	98	49
Neem (Azadinachta indica)	200	122	61
Avenue/Decorative plants			
Weeping willow (Polyathea longifolia)	100	63	63
Eucalythus (Eucalythus spy)	200	155	77
Yellow Duranta-shrub (Duranta plumerrii)			
Love grass (Chrysopagan aciculatis)			
Carpet grass (Azonopus compressus)			
Total	**1850**	**1163**	**63**

An estimate of a total of 1850 tree species excluding shrubs and grass were planted. The survival rate of trees planted in Africa can be 60-70% if adequate care is given to the trees, but can also be as low as 40% if not (TREE AID, 2015). As can be observed in Table 1, the survival rate for all the trees was considerable very high (i.e., 63%). For example, out of 200 grafted mangoes planted, 150 or 75% of them are currently in good health and providing shade and fruits to the Polytechnic community. As far as the shade trees are concerned, the survival rate was also very high. For example, in the table, it can be observed that out of a total of 300 Cassia (Cassia Spectabilis) planted, 223 or 74% are alive. Overall, after ten years of the project, there has been a significant improvement in the tree and shrub cover in the Polytechnic campus. It is concluded that adding trees to schools is a great way to make campuses more welcoming, provide shade for recreational purposes, and as well foster environmental stewardship. Figure 5 below presents a graphic account of planted mango trees surrounding the Library block (under construction in 2006). This was after one year of planting and care.

Figure 5. Mango trees surrounding the Library block

After ten (10) years of the project, the mango trees planted in selected parts of the campus are providing fruits, shade, and cooling to students and staff of the Polytechnic community. Figures 6, 7 and 8 below present a graphic account of the mango trees planted in the same Library block after ten (10) years in 2016.

Figure 6. Mango trees surrounding the Library block after ten years

Figure 7. Mango trees surrounding the Library block after ten years

Figure 8. Mango trees surrounding the Library block after ten years

Also, out of 200 Eucalythus (Eucalythus spy) trees planted, 155 or 77% of them are alive and serving as wind brakes in the Polytechnic Campus. Figure 9 below presents the Eucalythus (Eucalythus spy) trees planted around roads and lawns to serve as wind brakes.

Figure 9. Eucalythus (Eucalythus spy) trees within the Polytechnic campus

DISCUSSIONS

The success or realization of a tree planting project hinges on proper management of the established trees and shrubs (Wilson, 2103). Planting trees is just one step, but its management is very crucial to the success and fruition of the entire project. Before and after the actual tree planting, it was very crucial to involve all stakeholders (i.e., management, staff, and students). Specifically, project activities were preceded by stakeholder consultations to enhance awareness of the causes and consequences of land degradation, and available techniques for rehabilitation, and the benefits of trees. This led to the success of the project since the stakeholders bought into the project as very important to the Polytechnic community. Ultimately, this led to a sense of ownership, and participation in the project.

As indicated earlier, trees remain highly relevant to the environment and society. However, their value can only be realized if trees are managed effectively from the inception of a planting scheme to full maturity (Hirons & Percival, 2011). Planted trees generally require care to survive and grow, especially in the first few years. To this end, plans for monitoring and maintenance of the trees were developed and implemented. The project team through the farm hands engaged for the project routinely removed competing plants from around the trees, controlled insect pests, and watered the trees during the dry season. Cultural practices (i.e., mulching, watering, fertilizing and pruning) were also done as an important aspect in developing and maintaining healthy trees.

Challenges

Despite the attainment of very good survival levels of the planted species, the project faced a number of challenges. Forestry projects contain risk and uncertainty because of the long-term investment involved (Forestry Commission, 2014). Trees require more care. The labour requirements of land preparation and maintenance of the trees were the major problems faced. As indicated earlier, at the inception of the project, the Polytechnic campus was not walled. Damage to the trees and shrubs was mostly caused by pests such as insects, mice, and other mammals such as cattle, sheep, and goats. A huge chunk of the budget was therefore spent on tree protection. Also, adequate water supply especially in the dry season was a limiting factor.

Although the water storage system was envisaged to store enough water for use in the dry season, this was often not adequate to water the trees throughout the dry season.

Lessons Learnt

a) *Stakeholder buy-in to the project*: The consultations with relevant stakeholders in the Polytechnic and the immediate community were very useful for the success of the project. The workshops provided opportunities to discuss and clarify project aims and objectives. Particularly, the roles and responsibilities of project team members, the concerns and needs of the community who are the immediate beneficiaries, as well as benefit-sharing arrangements were discussed. This way, the commitment of the project team was achieved. This also resulted in effective participation and commitment from all the actors.

b) *Protection is essential:* Tending trees after planting creates favourable conditions for both the plants' survival and to stimulate a healthy, vigorous growth. Tending operations keep the plants from being suppressed by natural vegetation and protect them from other potential sources of harm such as animals, insects and diseases.

c) *Animal control***:** Animal damage to planted trees can be caused by smaller animals such as rodents, and larger animals like cows. Left unprotected, seedlings may be subjected to browsing and trampling by these mammals. Domestic animals such as goats, pose an especially severe problems. Several means were used to protect the plants. Physical barriers used included fences, and wire-mesh enclosures. However, fencing can be an easier means to install, but is an expensive option as witnessed in this project.

d) *Young tree maintenance:* As a result of proper tending and protection, the trees dominated the Polytechnic campus within the first five years after planting. At this point, the trees were essentially established. There will be need for other maintenance procedures such as thinning and pruning. This will require additional support from management since the project has elapsed.

RECOMMENDATIONS

Under the Ghana Forest Plantation Strategy (2015-2040), plans are set out for government and private sector reforestation of degraded forests with commercial plantations of exotic and indigenous tree species (Forestry Commission, 2014). The object is to create about 500,000 hectares of new forest plantations by 2040. However, there is lack of an integrated process embedding trees into the land use planning process at the conceptual, design, and implementation of school buildings in Ghana. Rainwater harvesting is just one of the solutions in the provision of supplementary water sources. Therefore rainwater harvesting should be introduced as a bylaw in the building guidelines and any new development should be encouraged to explore and apply the rainwater harvesting technologies.

Also, schools protect, nurture, and cultivate what is most important to our future – our youth. School are sedentary (i.e., the students and staff will remain throughout the year). We believe schools are also smart places to cultivate and protect what is arguably our most valuable resource – our environment. Through projects of this nature, students should be encouraged to learn about environmental issues and taking part in projects such as tree planting. School

nurseries could be developed in schools to serve the purpose of educating students in tree planting and management techniques. This can help overcome environmental problems such as deforestation and soil erosion.

There is also the need to develop systems to pass knowledge and information to all relevant organizations and to ensure the flow of expertise to agricultural and forestry extension agents in the field. Research is needed in tree planting and management. Documentation of best practices should be collected, published and distributed. But all these initiatives will require funding from the Government and other donors.

CONCLUSION

Climate change will affect rainfall and increase evaporation, which will put increasing pressures on our ecosystems (UNEP, 2009). At the global level, trees and forests are closely linked with weather patterns and also the maintenance of a crucial balance in nature (Verheij, 2004). In Ghana, there is considerable scope for the collection of rainwater when it falls, before huge losses occur due to evaporation, transpiration, and runoff all of which has consequences for the environment. Harvesting rainwater in wet periods, and utilizing the same for planting and growing trees offers a promising solution in the fragile, rainfed regions of the world (UNEP, 2009).

As indicated earlier, humans need trees to be alive because our life depends on the availability of air, water and food. Without trees, human life would be unsustainable. Trees help us get oxygen (air) and help in keeping our soil healthy so we can grow food. Trees provide a wide range of products (timber, fruit, medicine, beverages, fodder and oils) and life-supporting services (carbon sequestration, erosion control, soil fertility, shade and beautification). However, our trees and forests are rapidly disappearing at an alarming rate.

As part of conserving the environment, the project planted and grew trees in the Polytechnic campus. Schools protect, nurture, and cultivate what is most important to our future (i.e., our youth), and can be a fertile place for planting and growing trees. Adding trees to schools is a great way to make campuses more welcoming, create outdoor classrooms, shade recreation spaces, connect students to the benefits of trees and foster environmental stewardship. School campus tree projects are also highly visible and serve as model projects for thousands of students, parents and teachers together.

At the same, this will require the commitment of the schools (i.e., school management, project team members, teachers, and students) working in concert to plant and grow the trees. After planting trees, there is the need to continue to monitor and manage planted trees. Planted trees generally require care to survive and grow, especially in the first few years. Projects need to develop plans to monitor planted sites, and to actively maintain sites when necessary (i.e., removing competing plants from around the trees, controlling insect pests, watering trees during droughts).

Also, the policy environment in Ghana (i.e., Ghana Forest Plantation Strategy (2015-2040) needs to be enhanced to make tree planting compulsory in schools. For example, it possible to legislate that all new school buildings should incorporate planting of trees from inception. The building contractors of school buildings should plant trees right from the inception of the buildings. The buildings and trees can then be together handed over to the schools for the

schools to continue to care for the trees. Trees in schools can enhance the environment for teaching and learning.

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